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(58) Field of search
H4B

(54) Optical communications

(57) For military and civil secure communications each remote station 12-21 does not itself generate a light beam but instead merely reflects, suitably modified, a light beam transmitted to it by the home station 1-8. The home station codes a laser beam 9,10,1 which after beam expansion 2 is transmitted. The remote station detects reception at 17 and initiates modulation at 20 of that part of the received beam which passes through a beam splitter 14 to be reflected at 16 back to the transmitter. The modulation carries the desired secure information from the remote station.

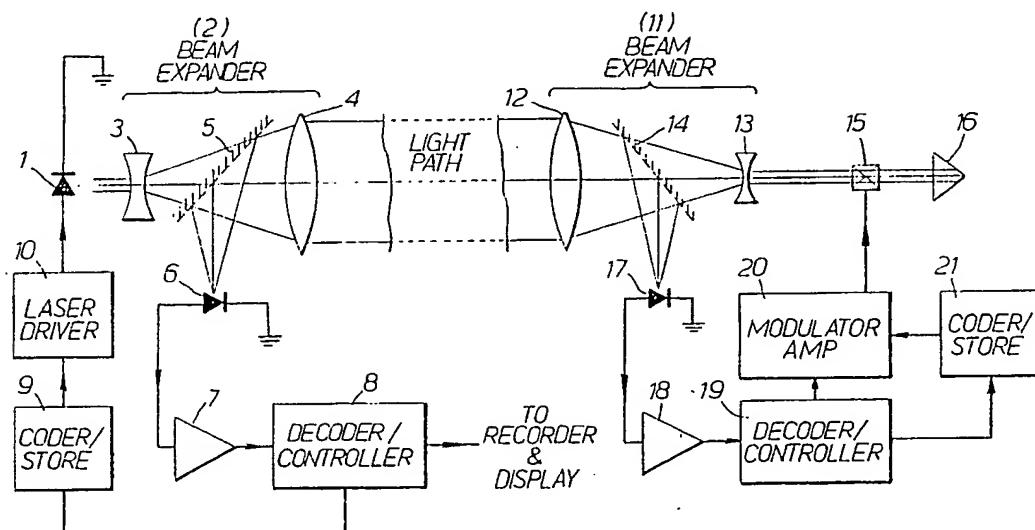


FIG. 2.

The drawing(s) originally filed was (were) informal and the print here reproduced is taken from a later filed formal copy.

GB 2 186 457 A

1/3

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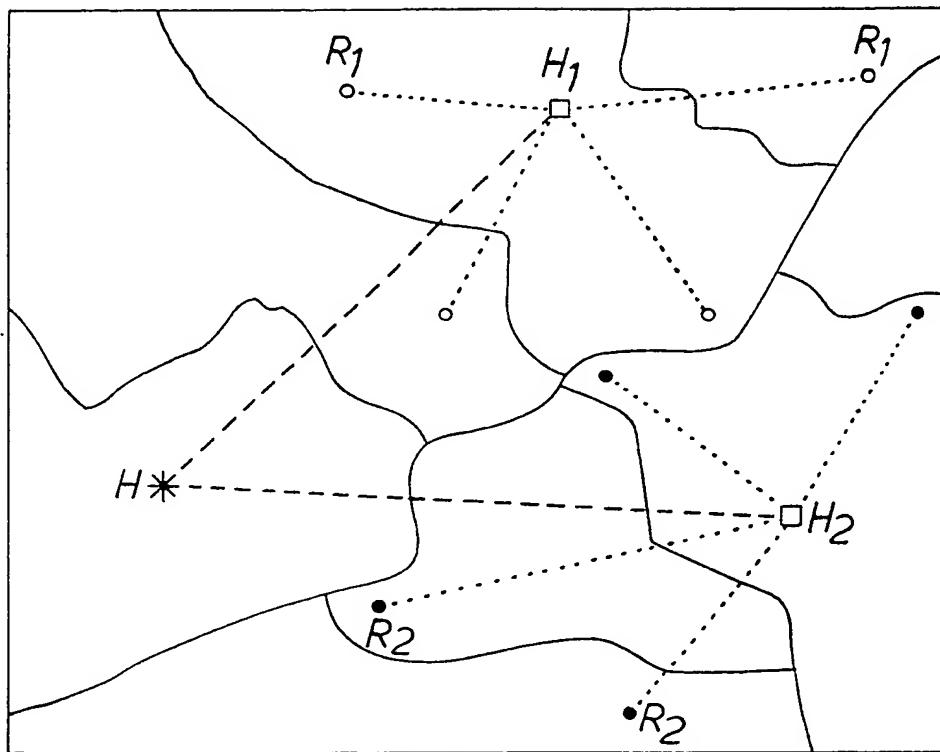


FIG. 1.

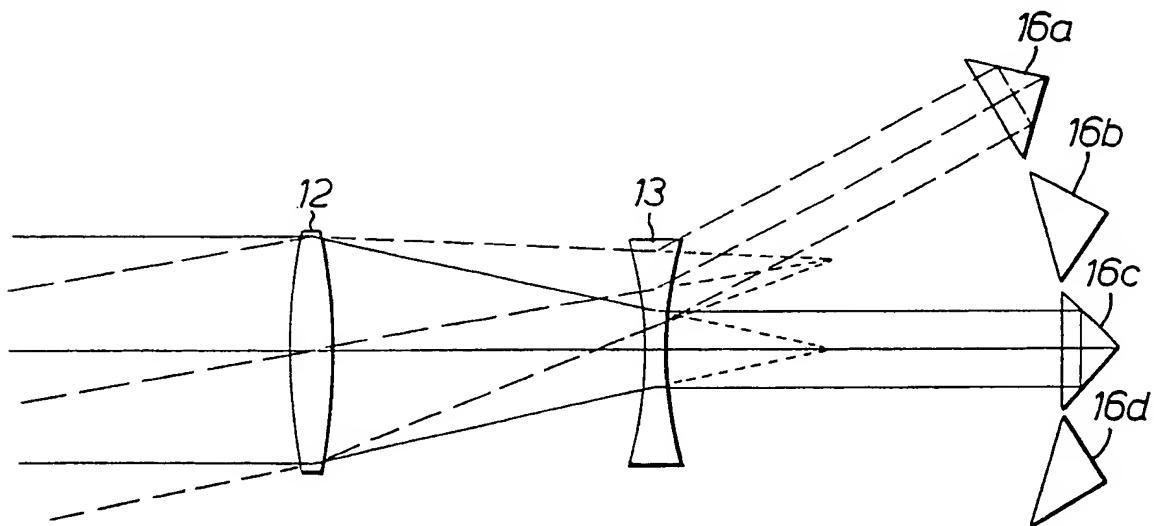


FIG. 4.

2/3

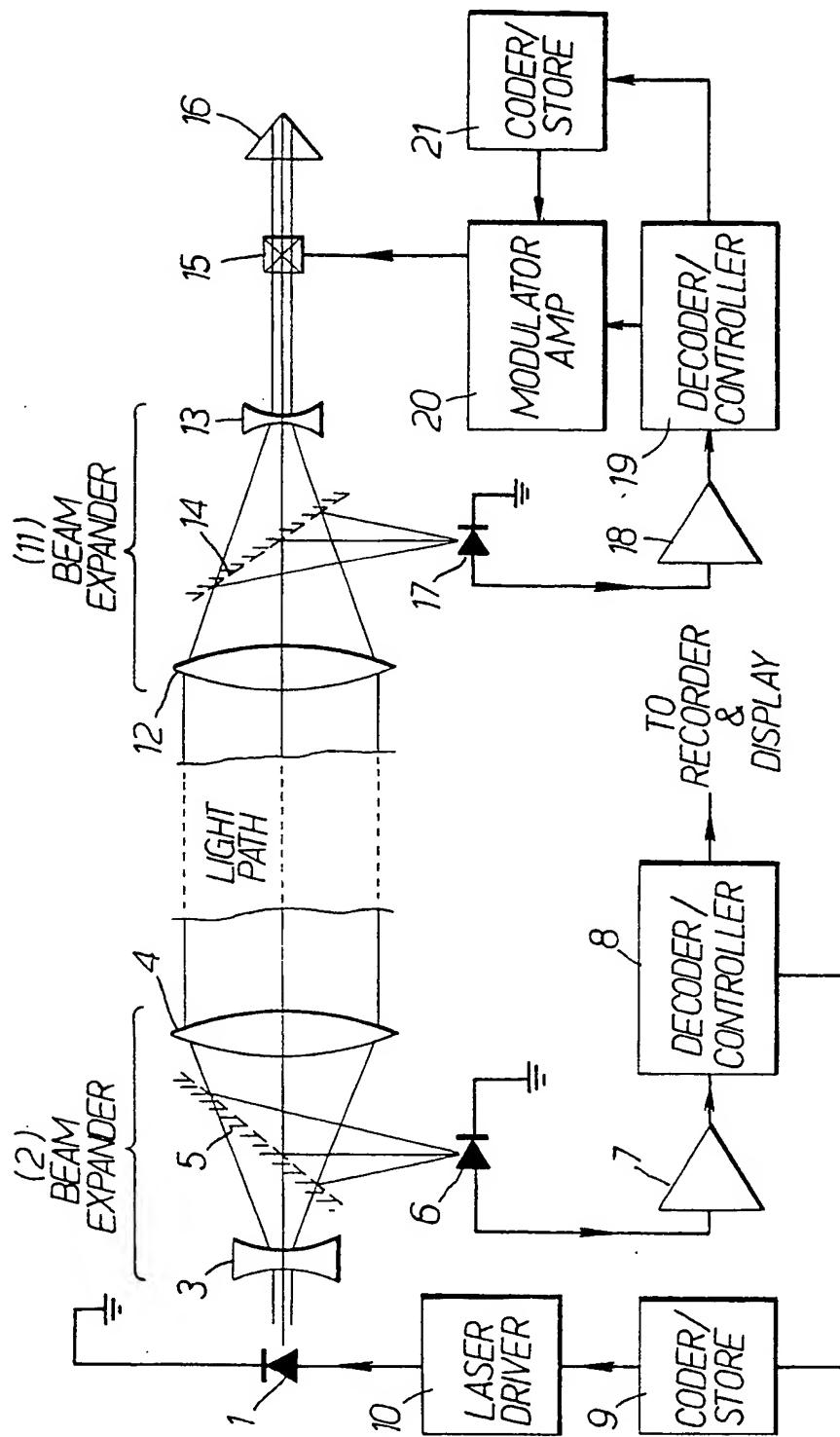


FIG. 2.

3/3

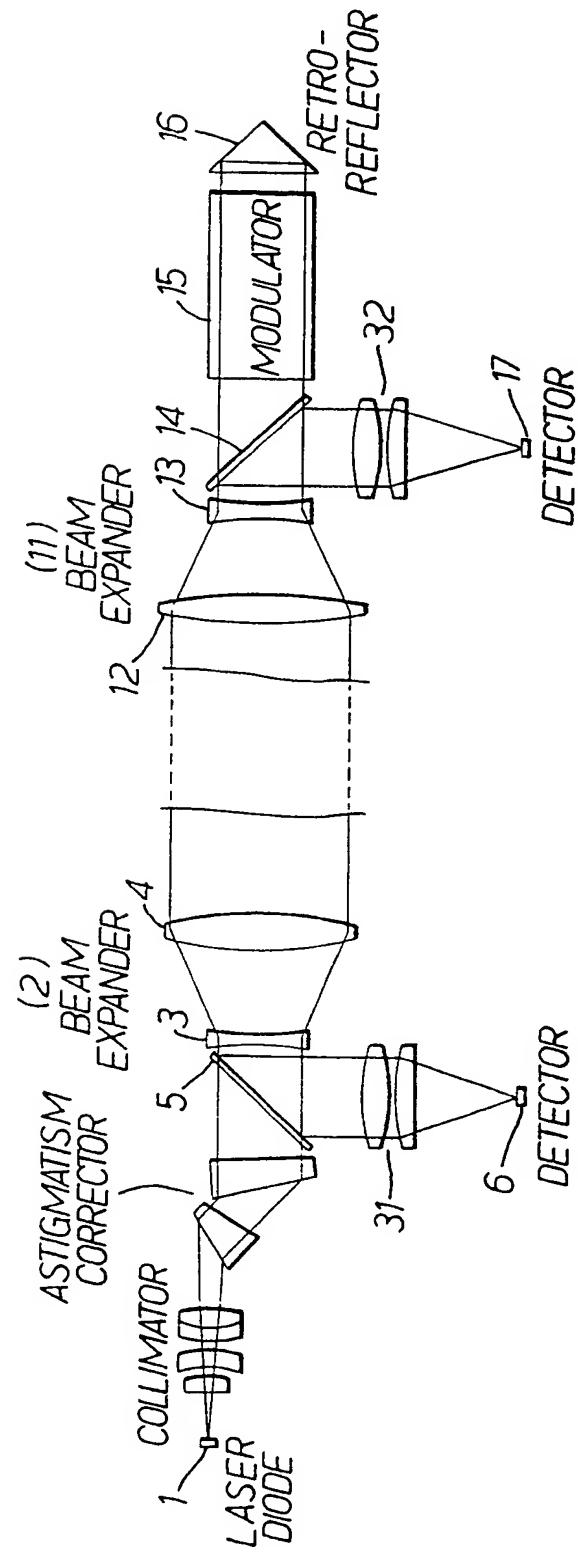


FIG. 3.

SPECIFICATION

Communications systems

- 5 This invention concerns communication systems, and relates in particular to systems allowing reasonably secure communications between a home and a remote station.
- In many fields, both military and civil, there exists
- 10 a requirement for a secure communications system that cannot easily be listened in on by unauthorised persons. This is especially desirable for a communications network in which a base, or home, station talks/listens to one or more out, or remote,
- 15 station. One way of making any system more secure is to arrange that it be a passive/active one - that is, it be one in which the or each remote station lies inactive until required, responding only to interrogation by the home station, and preferably
- 20 recognising a genuine interrogation before responding. Military uses for such a scheme are for IFF (Identification, Friend or Foe) systems, and for discrete or clandestine observation posts.

It has also previously been suggested that one

25 very secure form of communications system is that wherein the actual medium employed to carry the information being transmitted/received is not electromagnetic radiation in the radio frequencies but is instead light (itself electromagnetic radiation,

30 but in a much higher frequency band), and is very preferably light in the form of a light beam such as can be generated using a laser. Such a system is secure because, unlike a radio transmission, a light beam is to all intents and purposes unreceivable

35 except by a receiving device actually positioned in the beam itself.

The present invention proposes a combination of these two forms - the active/passive arrangement and the light beam arrangement - together with a

40 new feature, namely the idea that the or each remote station should not itself generate a light beam for emission carrying the required information but should instead merely reflect, suitably modified, a light beam transmitted to it by the home station.

45 In one aspect, therefore, the invention provides a communications system comprising a base, or home, station and one or more out, or remote, station, which system includes

a) in the home station, means for transmitting

50 towards any remote station a light beam that can carry the information to be transferred to the remote station, means for impressing that information onto the light beam, and means for receiving that light beam, possibly carrying information after reflection

55 from the remote station, and for abstracting any such information, and

b) in the or each station, means for receiving a light beam transmitted to the station from the home station, means for reflecting the beam back, possibly

60 carrying the information to be transferred to the home station, towards the home station, and means for impressing that information upon the light beam.

There may be as many remote stations as is required.

65 The light beam may be a beam of visible light or a

beam of invisible light (Infra-Red, for instance).

The means for transmitting the light beam may be any convenient such means. Advantageously it includes a light source and means for forming the

- 70 light output by the source into a beam. The light source can be a light-emitting diode, or more preferably a laser diode, or, for a long range or long wave length system, can be a laser such as a Neodymium YAG laser or a Carbon Dioxide gas
- 75 laser. The beam-forming means is conveniently that apparatus known as a "beam expander", and commonly comprises a negative lens and a positive lens whose focal lengths describe the expansion of the beam in their ratios. Such an arrangement is in
- 80 effect a telescope, and can be used both to transmit the beam to the remote station and to "receive" the reflected beam from the remote station. The telescope is preferably a terrestrial telescope because it enables the maximum field of view, but
- 85 any of the well-known popular variants (Gallilean, Huyghens or other types, including binoculars, and prism arrangements) may be used.

The means in the home station for impressing information upon the beam (or, more generally, 90 upon the light output by the source either before or after it has been formed into a beam) may be a modulator, preferably a pulse modulator, of any convenient variety. Typically it is an electrically-controlled device such as a Pockels cell, a

95 Kerr cell or a Liquid Crystal cell, but it could even be a mechanical device like a rotating shutter which is unmasked by a secondary shutter. The fixed output of any laser, for instance, can also be amplitude-modulated by a Bragg cell (or similar device). However, rather than modulate the fixed output of the source it may be possible - and preferable - to vary the source's output, and thus achieve modulation that way. For example, a laser diode source can be switched on and off to give a

105 pulse-modulated output.

The means in the home station for receiving the light beam reflected back from the remote station (and after it has been gathered by the "beam-forming" means) may also be any that is

110 convenient, and will frequently include a detector, an amplifier for the detector output, and (naturally) a decoder to abstract from the output the information that was carried by the beam. The detector is typically a silicon avalanche photo-diode, but could

115 equally well be a photo-multiplier, or (for CO₂ laser light) a cadmium mercury telluride diode. The amplifier is typically a low noise amplifier with appropriate filters and Automatic Gain Control. The decoder will be whatever is suitable depending upon

120 how the information was impressed upon the light beam.

The means in the or each remote station for receiving the light beam from the home station may be any convenient such means. Advantageously it

125 includes means for gathering the received light to a focus, and a detector for that light at that focus. The light gathering means is, in effect, a beam forming means (such as is used in the home station) operating "in reverse". The detector may, likewise,

130 be any one such as is used in the home station (for

detecting light received from the remote station), and may similarly be associated with amplifying means for the detector output.

The means in the remote station for reflecting the received light beam back the way it came may be a single means or - as could be advantageous to increase the field of view of the station - two or more means in a two (or even three) dimensional array. The or each single reflecting means may be any convenient form of retro-reflector (that is, a reflector which causes the light reflected therefrom to leave the reflector along the same pathway as it arrived along). A corner reflector is such a reflector, as are the various forms of spherical reflector now available.

The means in the remote station for impressing information upon the light beam before it is "sent" back to the home station may be any convenient such means - for example, the same as the corresponding means used in the home station.

The operation of the system as so far described can be as follows. First, the home station transmits to a selected remote station a beam of light. The remote station receives this light, and after detecting it activates its information-impressing means so as to impart to the reflected beam whatever information it requires to send to the home station. The home station then receives the reflected, returned, beam and acquires the information impressed thereon.

In a very much preferred embodiment the home station first transmits to the selected remote station a coded signal impressed upon the light beam that identifies the home station as being authorised to be sent information by the remote station. The remote station then receives, abstracts and decodes this signal, and responds thereto (by impressing its own information on the reflected beam) only if the signal matches some previously-acquired value indicating that the transmitter is duly authorised. Moreover, it is especially preferred that in any such system using coded signals to activate the or each remote station, the remote station light reflecting means be rendered substantially non-operative (as regards the interrogating beam transmitted by the home station), so as not to betray its position, unless and until the coded signal indicates that the transmitter is indeed authorised. This may be achieved in a number of ways. In the simple case the remote station's information-impressing means (a modulator, say) being placed in the beam pathway in front of the reflecting means, can itself prevent the beam reaching the reflecting means. However, in order the better to absorb all the received beam (and so reflect as little of it as possible) it may be preferred to switch the received light beam (using a pivotal mirror, for example) from a first pathway ending in a "matched" light-absorbent buffer to a second pathway ending in the light reflecting means.

In the system of the invention the home station transmits information to the (or each) remote station, and the latter transmits information to the former. As regards the information transmitted by the home station, this will generally be merely instructions for the remote station to transmit its information, preferably preceded by an identifying

code. The information transmitted by the remote station, however, could be of any variety, gathered in any way. For instance, the remote station could include a listening device counting and classifying

70 vehicles passing along an adjacent roadway, detecting them quite passively by virtue of their noise (also used to activate the device). Alternatively, the station might include a thermal imager recording the heat-signature and flight path of passing objects 75 such as aircraft, and even missiles. Naturally, in any particular group of remote stations the information and gathering means do not have to be the same. Moreover, the information could be gathered from another remote station - for, while the invention has 80 so far been described in terms of a net of a simple home station transmitting to and receiving from a number of remote stations each of which is entire in itself, it is not impossible that in a real situation a home station might itself be a remote state as well - physically, it might be arranged "back to back" with 85 a remote station - but for a different net. For example, each of ten first level remote stations might themselves be the home station for each of ten second level remote stations (and so on). In such a 90 case, each group of second level remotes gathers information for, and transmits it to, its own home station, which - as a remote in its first level net - then transmits it on to its own home station.

An embodiment of the invention is now described, 95 though only by way of illustration, with reference to the accompanying Drawings in which:-

Figure 1 is a schematic plan view of a communications system of the invention deployed in the field;

100 *Figure 2* is a schematic representation of the main components of a communications system according to the invention;

Figure 3 is a schematic representation similar to that of *Figure 2*, but of a slightly different system; 105 and

Figure 4 is a schematic representation of part of a remote station of the invention using an array of beam reflective means.

The "picture" of *Figure 1* is of an area of land 110 dotted with a number of home stations (as H, H₁, H₂) and a larger number of remote stations (as R₁, R₂). The remote stations are in groups, and within each group are positioned around a home station. Thus, all the R₁ remotes are positioned around, and netted 115 to, the H₁ home station. The H₁, H₂ home stations are themselves positioned around, and netted to, the H home station to which they act as remotes.

In operation, information gathered by each R₁ or R₂ remote is fed (along the dotted lines) back to its 120 home station (H₁ or H₂) which in turn feeds it back (along the dashed lines) to its home station (H).

The components of one embodiment of the invention are shown in *Figure 2*. In its simplest form the communications system of the invention 125 consists essentially of a home base with a transmitter comprising a modulable light source (1) whose output is expanded in diameter by a beam expander (2), constructed from a negative lens (3) and a positive lens (4), in order to form a narrow beam which illuminates a telescope (11; a beam

expander in reverse, and including a positive lens 12 and a negative lens (13) at the remote station. The collimated light in the dimensionally small beam output from the telescope (11) is allowed to pass 5 coherently via a light modulator (15) into a retro-reflector (16; shown as a corner reflector), returning whence it came, but now modulated with a message. Upon entering the home base beam expander 2 (now acting as a telescope), part of the 10 light is intercepted by a beam-splitting semi-mirror (5) and focussed on a diode detector (6), which has an amplifier (7) and a decoder (8) to receive and act upon the received message.

In a more preferred form the embodiment 15 includes, in the remote station, a beam splitter (14), to detect (17) the light from the home base, and to amplify (18) and act upon its own message which will be decoded (19) and identified as a proper interrogation message before the retro-reflector is 20 unmasked to permit the modulation of the reflection. In this embodiment the system is secure and discrete in its response. In operation the home station sends the correct code; the remote station, upon recognising the proper code, activates the 25 modulator amplifier (20) and the coder or data store (21) to drive the optical modulator (15) to acknowledge the home station's signal; upon receipt of a properly encoded signal from the remote station the home station coder/store (9) is activated to 30 change its output (e.g. to CW), and then the remote station sends its information.

The optics of a second embodiment of the invention, like that of Figure 2 but different in a number of minor ways, are shown in Figure 3. One 35 significant difference is that each beam splitter (5, 14) is positioned on the "narrow-beam" side of the respective beam expander (2, 11), rather than within the expander. As a result, it is in the collimated beam path, and so needs focusing means (31, 32) to focus 40 the diverted beam onto the respective detector (6, 17).

Figure 4 shows one way of increasing the effective field of view of a remote station. Instead of a single retro-reflector (16 in Figures 2 and 3) there is an array 45 (as 16a, b, c etc; only four are shown here, positioned as a linear array as opposed to an area array). Though it is not shown, there should also be a like array of detectors 17.

50 CLAIMS

1. A communications system comprising a base, or home, station and one or more out, or remote, station, which system includes
55 a) in the home station, means for transmitting towards any remote station a light beam that can carry the information to be transferred to the remote station, means for impressing that information onto the light beam, and means for receiving that light beam, possibly carrying information after reflection 60 from the remote station, and for abstracting any such information, and
65 b) in the or each remote station, means for receiving a light beam transmitted to the station from the home station, means for reflecting the

beam back, possibly carrying the information to be transferred to the home station, towards the home station, and means for impressing that information upon the light beam.

- 70 2. A system as claimed in Claim 1, wherein the light beam is a beam of Infra-Red light.
3. A system as claimed in either of the preceding Claims, wherein the means for transmitting the light beam includes a light source and means for forming 75 the light output by the source into a beam.
4. A system as claimed in Claim 3, wherein the light source is a laser diode.
5. A system as claimed in either of Claims 3 and 4, wherein the beam-forming means is that apparatus 80 known as a "beam expander", and comprises a negative lens and a positive lens whose focal lengths describe the expansion of the beam in their ratios, and is in the form of a terrestrial telescope.
6. A system as claimed in any of the preceding 85 Claims, wherein the means in the home station for impressing information upon the beam (or, more generally, upon the light output by the source either before or after it has been formed into a beam) is a pulse modulator.
90 7. A system as claimed in any of Claims 1 to 5, wherein, rather than modulate the fixed output of the source, the source's output is itself varied to achieve modulation.
8. A system as claimed in any of the preceding 95 Claims, wherein the means in the home station for receiving the light beam reflected back from the remote station (and after it has been gathered by the "beam-forming" means) includes a detector, an amplifier for the detector output, and a decoder to 100 abstract from the output the information that was carried by the beam.
9. A system as claimed in Claim 8, wherein the detector is a silicon avalanche photo-diode.
10. A system as claimed in any of the preceding 105 Claims, wherein the means in the or each remote station for receiving the light beam from the home station includes means for gathering the received light to a focus, and a detector for that light at that focus.
110 11. A system as claimed in Claim 10, wherein the light gathering means is a beam forming means (such as is used in the home station) operating "in reverse", and the detector is one such as is used in the home station (for detecting light received from the remote station), and may similarly be associated with amplifying means for the detector output.
12. A system as claimed in any of the preceding 115 Claims, wherein the means in the remote station for reflecting the received light beam back the way it came is a single means or - to increase the field of view of the station - two or more means in a two (or even three) dimensional array.
13. A system as claimed in Claim 12, wherein the or each single reflecting means is a corner reflector.
120 14. A system as claimed in any of the preceding Claims, wherein the means in the remote station for impressing information upon the light beam before it is "sent" back to the home station is the same as the corresponding means used in the home station.
125 15. A system as claimed in any of the preceding 130 Claims,

- Claims, wherein the home station includes coding means whereby a signal transmitted to the selected remote station may be a coded signal that identifies the home station as being authorised to be sent
- 5 information by the remote station, and wherein the remote station includes decoding means whereby it may decode this signal, and respond thereto only if the signal matches some previously-acquired value indicating that the transmitter is duly authorised.
- 10 16. A system as claimed in Claim 15, wherein, in any such system using coded signals to activate the or each remote station, the remote station light reflecting means is rendered substantially non-operative (as regards the interrogating beam
- 15 transmitted by the home station), so as not to betray its position, unless and until the coded signal indicates that the transmitter is indeed authorised.
17. A system as claimed in Claim 16, wherein, in order the better to allow the absorption of all the
- 20 received beam (and so reflect as little of it as possible) the light beam received in the home station is switchable from a first pathway ending in a "matched" light-absorbent buffer to a second pathway ending in the light reflecting means.
- 25 18. A system as claimed in any of the preceding Claims, wherein one or more remote station includes a listening device or a thermal imager.
19. A system as claimed in any of the preceding Claims, wherein one or more home station in one net
- 30 is as well a remote station in a second net.
20. A communications system as claimed in any of the preceding Claims and substantially as described hereinbefore.

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